Remarks:

Claims 1, 3-5, and 7-11 are presented for the Examiner's review and consideration. Claims 1, 3, 7, 8, 10, and 11 have been amended. Claims 12-20 are withdrawn. Applicants believe the claim amendment and the accompanying remarks presented herein serve to clarify the present invention and are independent of patentability. No new matter has been added.

Amendments to the Claims

Claims 1 and 3 have been amended to clarify that the suspension prepared by the claimed method is stable. Support for this amendment can be found throughout the specification as originally filed, for example, paragraph **[00020]** at page 5 and examples 1-3, paragraphs **[00037]-[00039]** at pages 10-11.

Claim 1 has also been amended to clarify that the length of time for sonication is 5 to 20 minutes. Support for this amendment can be found throughout the specification as originally filed, for example, paragraph **[00024]** at page 6 and example 1, paragraph **[00037]** at page 10.

Claim 11 has been amended to clarify that the polymeric material is adsorbed on the nanotubes forming an adhesive interface between the nanotubes and the polymeric material. Support for this amendment can be found throughout the specification as originally filed, for example, paragraph **[00011]** at page 4.

It is noted that minor amendments to claims 1, 7, 8, 10, and 11 have been made for proper antecedent basis and Markush language.

Amendment to the Specification

The specification has been amended at page 5, paragraph **[00019]** to correct a typographical error (inadvertent insertion of an underscore). No new matter has been added.

Objection to the Disclosure

The disclosure was objected to by the Examiner because it contains the following informality: at page 5, paragraph **[00019]** an underscore is inserted before the word "committing."

The disclosure has been amended herein to delete the underscore. Thus, Applicants respectfully request that the objection to the disclosure now be withdrawn.

35 USC 103(a) Rejections

Claims 1, 3-5, and 7-11 were rejected by the Examiner under 35 USC § 103(a) as allegedly being unpatentable over U.S. Patent 5,114,477 to Mort et al. (hereinafter "Mort") in view of Satishkumar et al. (J. Phys. B: At. Mol. Opt. Phys. 29: 4925-4934 1996; hereinafter "Satishkumar") and Ausman et al. (The Journal of Physical Chemistry 104(38): 8911-8915 2000; hereinafter "Ausman"). For reasons set forth below, Applicants respectfully submit that this rejection should be withdrawn.

It is noted that the references are described separately only to clarify what each reference teaches and not to argue the references separately.

Mort

Mort discloses an ink composition which comprises an aqueous or organic liquid vehicle, and as a colorant a fullerene, or a mixture of fullerenes (abstract). Mort discloses a general mixing step for preparation of the compositions; *See* column 8, lines 40-56. When using an organic liquid, such as toluene, the length of time for mixing is disclosed as 5 minutes; *See* example I. In contrast, when preparing a water-soluble suspension, the length of time for mixing is disclosed as 72 hours; *See* example II. Additionally, Mort discloses inclusion of surfactants or wetting agents to the compositions; *See* column 7, line 55 to column 8, line 3. The addition of sodium lauryl sulfate is disclosed in example I.

Satishkumar

Satishkumar discloses methods for opening, filling with metals, and closing carbon nanotubes. Satishkumar also discloses methods for preparing functionalized nanotubes by reaction with strong acids. *See* section entitled "Introduction" at page 4925. Although Satishkumar demonstrates that large structures of carbon (a micron or more in length) remain in the solution phase and are regenerated in the solid state on removal of the solvent; *See* page 4934, the regenerated nanotubes are aggregated; *See* Figure 6, page 4931.

Ausman

Ausman teaches that solution-phase handling of carbon nanotubes would be exceptionally useful; See page 8911, left column. To that end, Ausman discloses experiments investigating the room-temperature solubility of single-walled carbon nanotubes in a variety of organic solvents; *See* abstract and page 8915. Ausman identifies a class of non-hydrogen bonding Lewis bases that provide good solubility, but do not mention an aqueous solution of hydrophilic polymer; *See* page 8915. Thus, Ausman does not teach how to perform the solution-phase handling of carbon nanotubes without the use of organic solvents.

Current Invention

The invention, as currently claimed, provides a method for the preparation of an aqueous, stable suspension of essentially single, non-tangled carbon nanotubes that is simple and efficient. The invention also provides a dry form of well-separated carbon nanotubes that is easily stored and ready-for-use in a variety of applications, such as electronics and materials engineering; *See* specification at page 4, paragraph **[00012]**.

Single-walled carbon nanotubes (SWNT) are expected to exhibit superior mechanical (strength, flexibility) and electrical properties (insulating/conducting) as well as excellent thermal

stability. However, these properties are attributable to the individual tubes. As-produced single-walled carbon nanotubes align parallel to each other and pack into crystalline ropes, due to strong intertube van der Waals attraction. These ropes further aggregate into tangled networks. Aggregation is an obstacle to most applications, diminishing the special properties of the individual tubes. *See* Background of the Invention section of the specification and Bandyopadhyaya et al. (cited on the information disclosure statement filed on November 12, 2003).

In an attempt to solve this problem, the instant inventors mixed a water-soluble polymer, for example, gum arabic, with a powder of as-produced carbon nanotubes. This mixture was sonicated only for a short period of time, 20 minutes. A homogenous suspension of single-walled nanotubes was obtained and then stored at ambient temperature, and checked periodically for visual changes. The suspension remained unchanged after four months, and the nanotubes did not settle when tested with centrifugation at 4500 rpm for 30 minutes. Thus, the suspensions of carbon nanotubes prepared by the claimed methods are exceptionally stable. *See* specification at page 5, paragraph **[00020]**; page 6, paragraph **[00024]**; and example 1, page 10, paragraph **[00037]**.

Furthermore, it is very important to note that the aggregated arrays of nanotubes contained in the as-produced powder were dispersed into single nanotubes when prepared according to the claimed method. The as-produced carbon nanotubes contained aggregated arrays of ropes (Figure 1). The microscopic structure of the stable dispersions was investigated using cryo-transmission electron microscopy (cryo-TEM). Well-separated, single nanotubes, 2-3 nm in diameter, are clearly seen in the cryo-TEM images (Figure 4). Such separations of the tubes can be clearly observed in suspensions both before and after drying and re-suspension. These observations suggest that the adsorption of the polymer disrupts the van der Waals interactions between the tubes. *See* specification at page 5, paragraphs **[00014]** and **[00017]**; page 7, paragraph **[00026]**; example 4, page 11, paragraph **[00040]**; and example 5, page 12, paragraph **[00041]**.

It is also important to note that, in the prior art, surfactants were often used to assist in dissolving carbon nanotubes in water; *See* Ausman, page 8911, left column. The instant inventors tested several surfactants (SDS, CTAC, DTAB, dextrin, polyethyleneoxide) at various

concentrations and found that they exhibited minor or no dispersing effect on aggregated nanotubes and do not separate bundles into single tubes (Figure 3). Sediment appeared within minutes to hours after mixing. Thus, without dispersion of the nanotubes, these suspensions were not stable. *See* specification at page 5, paragraph **[00016]**; page 6, paragraph **[00025]**; and example 3, page 11, paragraph **[00039]**.

Argument

First, with regard to the main reference, the Examiner states that to the extent Mort describes "spherical fullerenes" versus carbon nanotubes, this does not impart patentability. The Examiner further states that fullerenes dispersed in hydrophilic polymer solutions, including gum arabic, are described in the literature and thus, the Examiner concludes that substitution of carbon nanotubes is an obvious expedient.

It appears that the Examiner concludes that fullerenes and carbon nanotubes can be used interchangeably for the same purpose or result. Applicants respectfully disagree with the Examiner's assertions and conclusions.

Although fullerenes and carbon nanotubes have many features in common, there are also many differences. *See* page 756 of Dresselhaus et al. (cited on the information disclosure statement filed on November 12, 2003). As narrow, seamless, graphitic cylinders having no exposed atoms that can be easily displaced, carbon nanotubes exhibit an unusual combination of nanometer-size diameter, millimeter-size length, and exceptional strength. Individual carbon nanotubes exhibit superior mechanical (strength/flexibility) and electrical properties (insulating/conducting), as well as excellent thermal stability. These superior properties are dependent on the tubular diameter and chirality. Since fullerenes do not share this same combination of topology and geometry with the nanotubes, they do not exhibit the same superior properties. *See* page 1974, left column of Sanvito et al. and section 19.2.2 of Dresselhaus et al. (both cited on the information disclosure statement filed on November 12, 2003). Additionally, when comparing fullerenes to single-walled carbon nanotubes, it is evident that there is a large gap in the intermediate size range; *i.e.* small spheres vs. long tubes. This intermediate size range could be of paramount scientific and technological

importance in practical applications. *See* page 1253, far left column of Liu et al. (cited on the information disclosure statement filed on November 12, 2003).

Accordingly, neither the cited art nor the prior art in general teaches or suggests that fullerenes and carbon nanotubes have identical properties and thus can be used be interchangeably for the same purposes or results. In fact, a quick internet search will pick up many sites on the subject that suggest the opposite, for example, The Fullerene Page, which states that carbon nanotubes are different materials than traditional fullerene-type materials (roundish cages), and so the carbon nanotubes have rather different properties (Kim Allen http://kimallen.sheepdogdesign.net/Fuller/nanotubes.html; cited on the information disclosure statement filed herewith).

Thus, Applicants respectfully submit that the Examiner's reliance on Mort as the main reference to support the rejection of the claim under 35 U.S.C. § 103 is misguided at best.

Accordingly, it is respectfully submitted that the cited references (Mort, Satishkumar, and Ausman) cannot be combined to provide the instant method or the products that result from carrying out the instant method. Mort is silent with regard to carbon nanotubes. However, with regard to fullerenes, Mort teaches both the use of surfactants and lengthy mixing periods (72 hours) for preparation of a water-soluble suspension. Satishkumar discloses methods for opening, filling with metals, and closing carbon nanotubes, but teaches nothing regarding stable suspensions of essentially single, non-tangled carbon nanotubes. Ausman teaches that solution-phase handling of carbon nanotubes, but does not teach how to perform the solution-phase handling of carbon nanotubes without the use of organic solvents. A person of ordinary skill in the art having the cited references in front of him/her would not be inspired or motivated to add carbon nanotubes simply to a water solution of a hydrophilic polymer and sonicate the mixture for a short period of time and expect to produce a stable suspension of essentially single, non-tangled carbon nanotubes, because the combination of the teachings from the cited references indicate that it can not be done. Even if one of ordinary skill in the art were to incorrectly assume that carbon nanotubes can replace fullerenes in the method of Mort, Mort uses surfactants and lengthy mixing steps. Ausman does not

suggest an aqueous solution of hydrophilic polymer and Satishkumar teaches no stable solution of essentially single, non-tangled nanotubes. Many prior artisans have attempted to comply with the hydrophobic character of the carbon nanotubes by introducing organic solvents or surfactants, or at least by increasing the hydrophobicity of the dispersing agents, but no one has tried the apparently futile procedure according to the instant invention. The instant inventors were the first to provide a simple method (short mixing periods and limited use of surfactants) for unbundling carbon nanotubes in aqueous solutions of hydrophilic polymers resulting in a stable dispersion (of carbon nanotubes) that can be dried into a ready-for-use powder of individual carbon nanotubes. The unbundling and stabilization of the single tubes is demonstrated unequivocally in the specification by a combination of X-ray scattering and cryo-TEM imaging. No such method or result is taught or suggested by the combination of the cited references (Mort, Satishkumar, and Ausman) or any other prior art for carbon nanotubes or fullerenes.

In order to better distinguish Applicants' method from the prior art, claim 1 has been amended to incorporate the short length of time for the sonication (5 to 20 minutes). Support for this amendment can be found throughout the specification as originally filed, for example, paragraph **[00024]** at page 6 and example 1, paragraph **[00037]** at page 10. Accordingly, amended claim 1 would not be obvious to one with ordinary skill in the art reading Mort in view of Satishkumar and Ausman under 35 U.S.C § 103(a). As claims 3-5 and 7-11 depend from claim 1, these dependent claims necessarily include all of the elements of the base claim. Accordingly, Applicants respectfully submit that the dependent claims are allowable over the references for the same reasons.

In light of all of the foregoing, Applicants request reconsideration and withdrawal of the rejection of claims 1, 3-5, and 7-11 under 35 U.S.C § 103(a).

Conclusion

In light of the foregoing remarks, this application is now in condition for allowance and early passage of this case to issue is respectfully requested. If any questions remain regarding this amendment or the application in general, a telephone call to the undersigned would be appreciated since this should expedite the prosecution of the application for all concerned.

The fee for a request for continued examination (RCE) pursuant to Section 1.17(e) in the amount of $810 is believed to be due and is enclosed herewith. Also the fee for submission of an information disclosure statement pursuant to Section 1.17(p) in the amount of $180 is believed to be due and is enclosed herewith. No additional fee is believed due. However, please charge any required fee (or credit any overpayments of fees) to the Deposit Account of the undersigned, Account No. 500601 (Docket No. 7640-X03-011).

Respectfully submitted,

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